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INTERNAL FACTORS INFLUENCING EGG PRODUCTION IN THE RHODE ISLAND RED BREED OF DOMESTIC FOWL II

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Cycles.—By cycles of egg production are understood the existence of periods of egg production alternating with periods either of decreased egg production or entire cessation of egg production. These cycles may be either long or short. The long-term cycles may have a period of a year. Shorter cycles exist with a period of three or four months, *i. e.,* winter, spring and summer and fall. There are still shorter cycles with periods measured in weeks, while one may also recognize irregular cycles. A litter, as defined by Miss Curtis ('14), is a short period of egg production alternating with a non-productive period and is well illustrated by broody birds, though it may occur in non-broody individuals. A "clutch," according to Miss Curtis, is the set of eggs produced on consecutive days. Its termination is marked by the appearance of a blank day.

The form of the yearly cycle depends to a considerable degree upon some of the internal factors under discussion, that is, it varies in different individuals. Egg production, as a rule, begins in the fall and winter, and continues at a fairly constant rate in most individuals until spring, when the rate rises somewhat in many individuals. Those that have been laying at a relatively high rate do not show this acceleration, at least not in as marked a degree. Sooner or later in a broody race broody periods appear, which interrupt egg production at fairly constant intervals. The rate, however, during the nonbroody periods shows no slackening, but on the contrary a very slight acceleration may be demonstrated, so that the lower egg production noted after the first broody period is due solely to the interruption of production. During the summer, the rate of egg production slackens, due almost entirely to the broody periods. The data for the 1913–14 flocks show that after June the rate of production is about constant for the next three months, largely because the first of July marks the point at which practically every individual in the flock has entered on its broody portion of the year. Some time in the late summer or during the fall, the various individuals stop laying and moult, some at one time, some at another, but usually at the end of a broody period. After the rest period in the fall, the birds gradually begin to lay again in mid-winter, somewhat as they did as pullets, except that the rate is slower as a rule. Except for this feature, the character of the second year's production is much the same as the first.

The winter cycle is regarded by the workers at the Maine Station (Pearl, '12) as the most important of all the cycles, at least from the standpoint of the investigation of the inheritance of egg production. They have found that it represents a definite period in the life history of the individual, among their Barred Plymouth Rocks. Furthermore, during this period, the greatest differences are to be observed in the egg production among individuals. They also find that high winter egg production is correlated with annual egg production, as would be expected except in the event that high egg production early in life tends to lower production in later life. In other words, a bird that is a good layer during the winter is probably a good layer at all times. There are other reasons, mostly of a practical nature for the use of the winter cycle as a measure of fecundity.

Taking the year as a basis the workers at the Maine Station recognize as its first characteristic the winter cycle beginning with the first egg of the pullet and extending to March 1. This date is taken as a convenient working point that falls near the biological division point.

During this period, flock production rises from zero to a maximum and then slows down somewhat toward its close. This slackening is due to a cessation of production on the part of most individuals while nearly all show at least a slackening of egg production towards the close of the winter cycle. The exact date at which the cycle ends varies with the individual, and may occur at almost any point during the winter months including March. Miss Curtis ('14), in another connection, has published the monthly records of a few hens that show this cycle. They are shown in Table VII. With one exception, No. 236, the birds all laid over 30 eggs. The evidence for a winter cycle is shown by the depressed egg production in January and February and is very clear. The records published by Gowell, '02, '03, also show this point.

TABLE VII

A PORTION OF TABLE XXV FROM CURTIS ('14) SHOWING THE WINTER EGG PRODUCTION OF A NUMBER OF BARRED PLYMOUTH ROCK PULLETS. THE DECREASED PRODUCTION IN JANUARY AND FEBRUARY OVER THE DECEMBER RECORDS IN NINE INSTANCES IS EVIDENCE OF A WINTER CYCLE.

Month	Pullet Number												
	218	139	446	516	192	259	204	478	212	184	211	236	441
1910													
October	...	3	...	...	...	...	...	...	...	...	...	...	...
November	15	19	17	15	18	8	5	13	6	12	8	1	9
December	25	18	27	24	24	11	16	24	8	14	15	0	18
1911													
January	13	19	6	9	14	13	4	10	11	6	5	0	14
February	13	10	15	9	0	16	13	0	8	11	5	0	16
Winter total	66	69	65	57	56	48	38	47	33	43	33	1	57

Pearl and Surface, '11, describe the other periods as follows:

> The next period (March, April and May) is the natural laying season. It corresponds to the egg-laying part of the natural reproductive cycle exhibited by the wild *Gallus*. . . . Naturally, therefore, a high mean and a low variability in production are exactly what we find characterizing the laying in each of the months of this period.
>
> The third period (June, July and August) is characterized by a gradually falling mean production and a variability gradually increas-

> ing. . . . This is the period in which the rearing of the chickens naturally occurs and it also represents an extension of the breeding season.
>
> The fourth period (September and October) is not easily separated from the third in respect to laying, but in general it is the period of moulting. . . . It is characterized by reduced laying and marked increased variability.

It is not clear from their accounts whether or not they consider that these periods extend through the second year or whether they are to be considered as characteristic solely of the pullet year.

Just how far the data on Barred Plymouth Rocks are applicable to our Rhode Island Reds is somewhat uncertain. At the outset it is evident that the small percentage of birds that show an interruption in their winter laying because of the presence of a broody period afford no evidence either for or against the existence of a winter cycle. Of the birds that do not go broody during the winter two classes can be distinguished, viz., those that show an interruption in their winter laying and those that do not. In the 1913–14 flock and in the 1915–16 flock from the original source, a large percentage of the birds show no interruption in production, not even a slump in the rate of production. Such birds lay at an approximately constant rate through the late fall and winter months, and on through the spring. Among the records of the main portion of the 1915–16 flock are many that show an interruption or else a slackening of production. Of these birds it can be said that they have a winter cycle. But there are two points about these records that make it difficult to interpret the interruption in production as an index of a cycle. First, the interruption may occur at almost any time during the winter followed by a resumption of production in mid-winter, and second, some individuals show more than one period of nonproduction. While there is definite evidence that a winter cycle exists in *some but not all* Rhode Island Reds, the possibility that some at least of these interruptions of production may be due to environmental factors must be fully recognized.

As already noted, there are many Rhode Island Reds which show no sign of a winter cycle. Whether this means that such birds do not have a winter cycle, or whether it means that some other factor covers up an underlying cycle is uncertain. In many instances these birds are very much like the Barred Plymouth Rocks noted by Pearl and Surface, '11, who state:

> Many birds of course have no proper winter cycle at all. They begin to lay for the first time in January or February and keep on laying without any large break straight through the spring cycle.

But there are many other Rhode Island Reds that begin to lay in October, November and December and lay through the winter and spring without any breaks whatsoever. Moreover, those birds that begin to lay in January or February for the first time very rarely show any break whatsoever. For these instances where the birds begin to lay late in the winter it is conceivable that the winter cycle might extend well into March but that the comparatively mild weather at that season of the year would tend to eliminate the rest period and thus conceal the winter cycle. But this argument cannot be applied to those instances in which the laying is continuous from its start in October, November or December right through the spring. There seems no reason to speak of a winter cycle for this class of Rhode Island Reds.[4]

The spring cycle, in Rhode Island Reds, in so far as it can be differentiated from the winter period, differs chiefly from that of the Barred Rocks in extending nearly through June, since the end of June marks the point at which practically every bird that will go broody has become broody at least once. Egg production is at its maximum at the beginning of this period due to active laying on the part of practically all individuals but falls sharply

[4] Later work on this point demonstrates, beyond doubt, that the presence of a definite winter cycle is not characteristic of our strain of Rhode Island Reds as a whole. There is some evidence, moreover, that the winter cycle is a Mendelian recessive, the dominant allelomorph being continuous winter production. For details see Goodale, '18.

after its middle, the rate of decline being much greater than for the Barred Plymouth Rocks.

The summer period may be considered to be July, August and September. Practically all the birds of the flock are laying in broody cycles with egg production remaining at approximately a constant level, while considerable partial moulting is going on. It passes gradually into the fall period which is characterized chiefly by the cessation of egg production—usually coinciding with a broody period—and the onset of the fall moult together with some slowing in rate of production of those birds that are laying. Biologically the fall period overlaps the calendar year since it may extend into December. The question of egg production in the fall, at the end of the pullet year, is on rather a different basis from that of the other seasons of the year. The egg producing mechanism of the hen seems to be in a peculiarly unstable condition and unless great care is exercised may cease functioning in response to slight adversities in environment. Some hens, however, and this is really the important point, continue to lay throughout the fall months with the same regularity they exhibited in the spring. This affords us an opportunity to build up a strain of birds that will be persistent layers throughout the year.

Thus, persistency in egg production through the fall months enters in as a factor in determining the total egg production as has also been emphasized by Rice ('14). Some birds cease laying relatively early in the fall, say late in August or September; others, however, of the same age, breeding, and under the same conditions, continue to lay all through the fall, at approximately the same rate of production as during the summer months, although the rate may fall off slightly. Now, these birds will have quite a different total record from those that stop early in the season and if one examines his records he finds that while many persistent layers are also good producers early in the season, nevertheless a great many of the birds that were good layers during the winter are not persistent layers during the fall, while some birds with low winter records are good fall layers.

Other kinds of cycles, which are described in the following paragraphs, have been noted in the Rhode Island Reds. In broody individuals, where the practice is followed of "breaking up" the hen, a series of cycles is introduced, marked by broody periods alternating with an egg production period. If the natural course of events is not interfered with in the case of broody hens, the broody period lasts until the chicks have hatched. Then the period of rearing takes place. Toward the end of this period the hen begins to lay and the cycle is repeated.

There is also a short time cycle of one or two weeks which needs little discussion at present. It is shown by an acceleration in rate of egg production followed by a decline somewhat as follows: Egg—blank—egg—egg—blank—egg—egg—egg—blank—egg—egg—egg—egg—blank—egg—egg—egg—egg—blank—egg—egg—egg—blank—egg—egg—blank—egg—blank—egg—blank—egg—blank—and repeat. Although one often finds records that approximate closely the above scheme, their rarity suggests either that the fluctuations in rate are due directly to some extraneous circumstance or, if there is a fundamental rhythm of this sort, that it is subject to disturbance from the environment. Whatever may be the cause, at present it is doubtful if it is indicative of an internal factor.

The next type of cycle is that exhibited by certain hens which lay at a relatively high rate for a time and then stop. This period may correspond to the term often used by poultrymen when speaking of a hen's clutch. Here again we are confronted by doubt as to the causation of these blanks, for many hens do not have such pauses in production. Once they begin laying they continue without any considerable vacant period (not exceeding three or four days) until the onset of the first broody period.

Stamina.—A strong bird is readily distinguished from a weak one, but it is difficult to separate the birds permanently according to a definite standard since it is impossible to secure a constant environment. A fairly uniform environment in the sense that all birds are exposed to the same external conditions at any one moment is fairly easily secured; but since the external conditions, particularly weather conditions, are very variable and follow no definite course, and since a bird's vigor is a resultant of its own inherent strength of resistance against the environment, it is clear that the objective vitality observed in each member of a flock may be unequally affected by the surroundings.

The evidence available on the relation of vitality to fecundity thus far points in two more or less opposite directions. Many birds of low vitality have made not only excellent but even high records. On the other hand, birds of strong vitality may make low records. At the same time there is a point at which the vitality becomes too low for good egg production. In the fall of 1913, thirty-eight birds graded early in the fall, before laying commenced, as "poor" in respect to vigor, were put in the laying houses. They had an average record for the winter period of only 20 eggs against an average of 38 for the entire flock, including the poor birds. Low vitality evidently depressed egg production in this instance; mainly, through retardation of the time of commencement of laying rather than by slow production. The influence of lack of vigor on winter egg production is shown in Fig. 9, where the curve of winter egg production for the entire flock is represented by the continuous line and that for the "poor" birds by the dotted line.

Occasionally, birds of low vitality may make excellent egg records. In one family in particular, the birds were of distinctly mediocre quality, as evidenced by their weight, activity, hatching quality of eggs and viability of chicks and yet they were able to make high records, the average for the family of seven individuals being 63.3—ranging from 33 to 81—for the winter period, with a yearly average of 192.4 for the five birds that survived throughout the year, and with a range of 154 to 210.

Moult.—Moulting exercises some influence on the number of eggs produced, since birds that are moulting often do not lay, particularly during the fall moult. Moulting itself may be induced at certain seasons of the year by changes in management, especially those changes that tend to stop egg production. Such changes apparently change the course of the metabolism of the bird. Broodiness in late summer and early fall appears to be a common cause of the onset of a moult and consequent cessation of egg production. At least one might draw this conclusion from the fact that egg production, as the usual rule, ceases with a broody period, for in most instances the last egg laid in late summer or early fall coincides with the beginning of a broody period. It is not clear, however, whether the moult starts because the bird has reached the limit of her production period, or whether the moult begins because of the interruption to egg production due to the onset of the broody period.

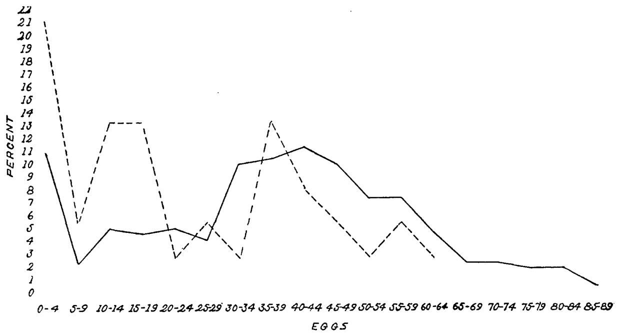

FIG. 9. The effect of low vitality on winter egg production. The graph shows the percentage of the flock of 1915–16 laying the specified number of eggs. The continuous line is for the entire flock. The dotted line is for that portion of the flock graded "poor" or of low vitality, before being placed in the laying houses.

In the Rhode Island Reds we have observed a partial moult that begins in the early part of the summer and as a rule seems to affect egg production very little. In the autumn this partial moult is followed by a more extensive (often complete) moult attended by cessation of production. It is possible that the summer moult has been induced by broodiness, but that the hens are broken up so quickly and the impulse toward resumption of egg production at this season is so strong that it inhibits the moult at various stages.

Pullets that begin to lay very early in the fall very often undergo a moult during the latter part of the same fall. It is not clear that early production of itself tends to induce the moult so long as the birds affected are not hatched too early in the season. The moult is more commonly observed in pullets that are hatched very early in the season and which begin to lay in August and September. Such birds rarely make a continuous record but instead stop laying after producing a variable number of eggs and moult much like birds from fifteen to eighteen months of age. In the flocks with which we have been dealing the variability in maturity has induced some complications in handling the flocks. If an attempt is made to hatch birds sufficiently early in the season, so that a good share of them will begin laying in November, some begin too early, lay a while, and then moult.

Rate and Rhythm of Production.—The percentage rate of production at any time and for any period may be taken as the number of eggs times 100, divided by the length of the period involved, measured in days. Rate is an important factor in determining egg production, but in the Rhode Island Reds is of quite secondary importance as compared to date of first egg (and of course age at first egg).

The distribution of the percentage rate calculated for the winter period (between the first egg of each pullet and March 1) for the flock of 1913–14 has been determined and the graph shown in Fig. 10 plotted. The curve shows a considerable homogeneity of rate in the flock. Since the general trend of events, such as accidents, temporary ailments, etc., is of such a nature that some birds do not attain their natural inherent rate, the curve shows a very gradual slope at the left-hand side up to about 30 per cent., a somewhat more rapid rise between 30 and 50 per cent. and a much sharper rise beyond 50 per cent. The mode comes at the 61 to 70 per cent. group, while the maximum rate does not exceed 90 per cent. It is interesting to note that 8.5 per cent. of the flock laid at a rate exceeding 80 per cent. for the entire winter period.

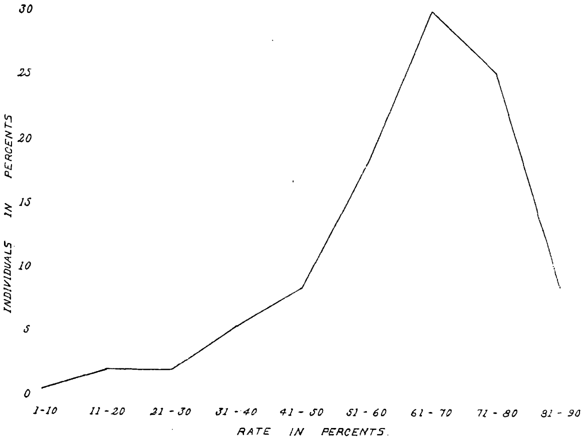

Fig. 10. Percentage rate of production for the winter period. The percentage of the flock laying at the specified rate is shown by the ordinates, the rate by the abscissæ. Flock of 1913–14. M = 62.50, S. D. = 15.77, C. V. = 25.23.

The effect of variability in rate on total production for a definite period is shown by the records given in Fig. 11.

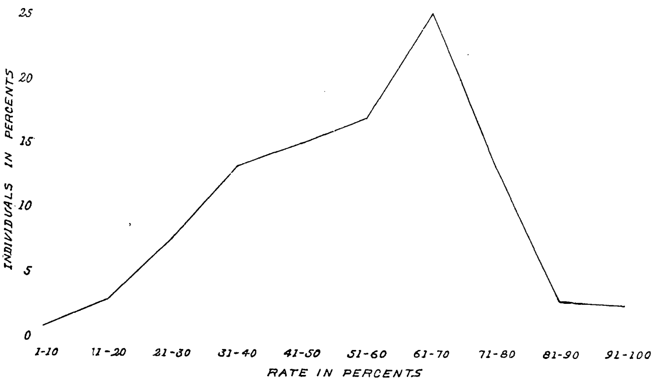

Fig. 10*a*. Percentage rate of production for the winter period. The percentage of the flock laying at the specified rate is shown by the ordinates, the rate by the abscissæ. Flock of 1915–16. M = 54.59, S. D. = 18.52, C. V. = 33.93.

No. 49 HATCHED MARCH 16, 1913. AGE AT FIRST EGG, 248 DAYS

Date 1913–14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.																			/	/	/		/	/	/	/	/		/	/	■	10	
Dec.	/	/		/	/	/	/		/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	28	
Jan.	/	/	/		/		N	/		/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/		/	/	/	/	25	
Feb.	/	/	N	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	■	■	■	25	88
Mar.	/	/	/	/	/		/		/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	28	
Apr.	/		B L			A	N	N	N	N N	N N	N B L		A N	/	/	/	N	/	/	/		/	/	/	/	/	/	/		■	14	

No. 4797 HATCHED MARCH 21, 1915. AGE AT FIRST EGG, 236 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.												/		/		/	/		/	/		/	/		/	/		/	/		■	12	
Dec.	/		/	/		/	/		/		/	/		/		/	/		/		/		/		/	/		/	/		/	19	
Jan.	/		/		/		/		/		/		/		/		/		/		/		/			/		/		/		15	
Feb.	/		/		/		/		/		/	/	/	/		/	/		/		/		/	/		/	/		/	■	■	18	64
Mar.	/		/	/		/	/		/	/		/	/	/		/	/	/		/	/	/		/	/	/	/		/	/	/	23	
Apr.	/		/	/	/		/	/		/	/	/		/	/	/	/		/	/	/	/		/	/	/	/	/		/	■	23	

FIG. 11. Types of daily egg records with special reference to the winter egg production, although the records for March and April are also shown. All three pullets matured near the average age. No. 49 is that of a pullet that laid continuously at a high rate. No. 4797 is that of a pullet that laid continuously at a rather slow rate of production, while No. 5080 is a pullet that laid intermittently and at a slow rate. This last would seem to be a mediocre producer in Pearl's sense.

Number 49 laid at an exceptionally high rate. On the other hand No. 4797 laid at a rather low rate for a bird that produced eggs continually throughout the winter. Although she began laying several days earlier in the year than No. 49, she produced 24 eggs less, due to her slow but steady rate of production. An entirely different type of rate is shown by No. 5080. This bird is a true mediocre producer in so far as may be judged from her record. She laid her first egg at a fairly early date and fairly early in the season but her rate of production was very low. The eggs, too, were produced at haphazard intervals. Her record is to be compared with that of No. 4568 (Fig. 4), which laid the same number of eggs but all in the last part of February. Records similar to those of No. 5080 are shown by Nos. 274 and 280 (Fig. 12), both Barred Plymouth Rocks in one of the contest pens at the Essex County Agricultural School. Another type of rate is shown by No. 4815 (also Fig. 12), which exhibits also a well-defined winter cycle. This bird matured early, began laying early in the season, and laid well for about six weeks. Then she stopped entirely and did not lay at all again until late in February.

While rate may be considered independently of the rhythm, *i. e.,* rhythm may be ignored; rhythm can not be considered apart from rate. A hen may lay twelve eggs in a month and the rate be described as such or as 40 per cent. without paying any attention to the sequence in which the eggs appear, but if the rhythm be considered, attention must be paid to the sequence between eggs. Thus, two blank days may repeatedly alternate with one blank day between eggs, producing a regular rhythm, or the twelve eggs may be laid in groups of two, three, or more eggs on successive days and then a considerable period of blank days intervene, the rhythm in this instance being irregular. A certain degree of regularity of rhythm is closely associated with high rate of production, though some birds of relatively low rate lay in a regular rhythm (Fig. 11). Most low-record birds, how-

No. 5080 HATCHED MARCH 28, 1915. AGE AT FIRST EGG, 244 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.																										N	/				■	1	
Dec.																				/					/		/		/			4	
Jan.																																0	
Feb.												N	NN		/		/		/		/		/	/		/				■	■	7	12
Mar.	/		/		/		/						/		/		/		/		/	/		/		/		/		/		14	
Apr.	/	/		/	/		/		/	/		/	/		/	/		/	/		/	/		/	/		/	/	/		■	20	

FIG. 11. (*Concluded.*)

No. 274 HATCHED 1915. AGE AT FIRST EGG, UNKNOWN

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.																															■	0	
Dec.			/		/				/																	/		/				5	
Jan.															/									/			/					3	
Feb.			/				/																				/	/	/	■	■	5	13
Mar.	/																								/		/	/				4	
Apr.		/	/					/	/	/	/			/	/		/	/	/		/	/	/			/			/	/	■	17	

FIG. 12. Daily records of two Barred Plymouth Rocks (Nos. 274 and 284) in the contest conducted by the Essex County (Mass.) Agricultural School. They are mediocre producers. The third record, *i. e.*, of 4815, a Rhode Island Red, shows a long winter rest period, *i. e.*, a winter cycle.

No. 284

HATCHED 1915. AGE AT FIRST EGG, UNKNOWN

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.......																															■	0	
Dec.......														/		/			/													3	
Jan.......																/		/	/	/	/	/	/		/	/	/	/	/	/	/	14	
Feb.......			/				/	/																	/					■	■	4	21
....							/		/	/	/		/	/	/	/		/	/		/	/		/	/		/					15	
Apr.......				/		/				/		/	/	/	/		/										/		/	/	■	11	

No. 4815

HATCHED MARCH 21, 1915. AGE AT FIRST EGG, 227 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.......			/		N	/		/	/	/	/		/	/	/	/	/		/	/	/	/		N	/		/	/	/	/	■	20	
Dec.......	N	/	/	/		/	/	/			/		/	/		/		N	/		/								/			13	
Jan.......																																0	
Feb.......																					/		/	/		/	/	/		■	■	6	39
Mar.......	/	/	/		/	/	/	/	/		N	/	/		/	N	/		N	/	/		N	/	/	N	/		/		/	19	
Apr.......	/			/	/	/	/		/	/		/		/	/	/	/	/		N	/		/	/	/	/		/	/	/	■	21	

FIG. 12. (*Concluded.*)

ever, have an irregular rhythm. While the observed rhythm is rarely entirely regular, yet each hen tends to produce eggs according to a rhythm that is characteristic to a certain limited degree for that individual. Superimposed on the daily rhythm are evidences of other rhythms having a beat measured by months or years. Although from another standpoint egg production is a more or less continuous process, at least in so far as the growth of the yolk is concerned, even though the fluctuations in the activity of the albumen and shell glands may be more pronounced, the rhythm may be considered as it appears on the record sheets, *i. e.*, the rhythm shown in the deposition of the eggs. Various types of rhythm have been observed. If, as a working basis, it be assumed that an egg a day represents a standard rhythm, although this high rhythm is rarely reached for extended periods, it will be found that some hens lay every other day, or we may say a one half rhythm, others two thirds, *i. e.*, two days out of three, others three fourths and so on. The three fourths or four fifths rhythm is common among most good layers. Occasionally the series may be repeated without the intervention of a zero day as is shown by the time of day the eggs are laid, for if the time of day at which the eggs are collected from the trapnests is recorded, the rhythm is shown even better than by the daily records. It has been our practise to visit the nests about every hour and a half and to record the time the eggs were gathered in units of a half hour. Thus the approximate time that each hen drops her egg is known. Rhythm, as shown by the time of day a hen lays her eggs, is an index of the essential continuity of the activities of the ovary in the growth of the ova, rather than of any rhythm in its activity, since the interval between eggs is more uniform than when the daily record only is used. One may perhaps infer that there is some rhythm in the activities of the oviduct since it is known that the stimuli for its activity comes from the presence of the yolk in its lumen. However this may be, the several types of rhythm shown by the daily records are found to depend very much on the time of day that the eggs are laid.

None of the various types of rhythm, *i. e.,* one half, three fourths, etc., are characteristic of any one hen, although many individuals seem to center about a particular rhythm, *e. g.,* two thirds. A bird with this rhythm may fall to the one half type but does not often, except in the spring, exceed the three fourths type. While little stress can be laid on this point, it is interesting to note this tendency toward a definite rhythm in some individuals. But aside from these considerations, birds of the same age, which begin to lay at approximately the same time and which do not become broody, do not lay with the same rhythm. Thus, of two full sisters, hatched the same day, one laid only about every other day, while the second laid about five days out of six. The rhythm, then, is quite an important factor in determining the number of eggs laid.

Various causes may interfere with the normal rhythm, such as causes that interfere with the formation and growth of the egg, and other causes such as environment, season, method of management and internal factors such as broodiness. In many birds evidences of a rhythm with a period of some length may be noted as shown on page 215. The example given is of course idealized but actual records of nearly the same type may be observed.

In this connection the question of the nonproductive periods, usually of short duration, that occur in some records and which produce irregularities in the rhythm may be discussed. As will be pointed out later, broodiness is responsible for some of these periods. A similar period, that may be noted in some hens' records during the winter, may be taken as an index of the existence of a winter cycle. But other individuals may have two or more such periods or may have a single period fairly early in the winter (No. 4529, Fig. 13). Some of these periods may be inherent in the individual's makeup but

No. 4529 HATCHED MARCH 7, 1915. AGE AT FIRST EGG, 214 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	To-tals	
Sept.																															■	0	
Oct.							7.5	7.5	9	9	10.5	9	9	9	9.5	1		7.5	7.5	7.5	9	4.5		10.5								16	
Nov.																															■	0	
Dec.																						N4										0	
Jan.											N3	10.5		8	9	9	11	1				9	3		7.5	10.5	3	N 11.5	9	10.5	3	14	
Feb.		7.5	10.5	3		7.5	10.5	3			10.5	11.5	2		7.5	9	9	10.5	10.5	3			9	10.5	7.5	9	10.5	9	10.5	■	■	22	52
Mar.	10			N 10.5	N4		N1		N1		N9					N9	N3		N 9.5	N3		N9	N9	N 11.5	N3	N 12	N3		N9	9	11	3	
Apr.	3		7.5	N11	11	1	N3		N 7.5	N1	N9	N9	N9	9	N3	9	10.5	N 10.5	3		7.5	9	10.5	10.5	9	10.5	9	10.5	10.5	N 3	■	17	

No. 5032 HATCHED MARCH 28, 1915. AGE AT FIRST EGG —

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	To-tals	
Nov.																											N4	N 7.5	N1		■	0	—
Dec.	N 10.5	N 2.5		N 9	N 3		N 10.5	N 1	N 4		N 9	N 3		N 1	N 2.5		N 1	N 3		N 1		N 3		N 3		N 3						0	
Jan.																							N 12	N 1	N 3		N 7.5	N 10.5	N 1	N 4.5		0	
Feb.	N 9.5																									N 7.5	N 12	N 1	N 1	■	■	0	0
Mar.	N 1	N 4		N 3		N 3		N 7.5	N 10.5	N 1	N 4		N 9	N 10.5	N 1	N 4		N 9	N 3	N 3		N 10.5	N 3	N 3		N 9	N 10.5	N 1	N 4		N 9	0	
Apr.	N 10.5	N 12	N 3		N 9	N 10.5	N 1	N 4		N 9	N 10.5	N 10.5	N 3		N 7.5	N 10.5	N 10.5	N 10.5	N 3		N 7.5	N 9	N 10.5	N 3	N 4	N 7.5	N 9	N 10.5	N 3	N 3	■	0	

FIG. 13. Types of Records. No. 4529 is that of an early maturing pullet that laid discontinuously but nevertheless made a fairly good winter record. Nos. 5032 and 246 are nesters, *i. e.,* birds that visit the nests regularly but do not lay. The time at which the egg was collected or the hen ready to leave the nest is shown by the numerals. ".5" is used for the half-hour period.

No. 246 HATCHED MARCH 30, 1913. AGE AT FIRST EGG —

Date 1913–14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	To-tals	
Nov........																															■	0	
Dec........																																0	
Jan........														N 3		N 11.5		N 9.5	N 3		N 9.5	N 1		N 11.5	N 3.5		N 1.5		N 11	N 3		0	
Feb........	N 1		N 1		N 11.5		N 1.5		N 9	N 3																		N 4	■	■	■	0	0
Mar........				N 11.5 N2			N 8	N 11.5	N 3.5		N 10.5	N 2		N 10	N 1	N 2		N 9	N 1.5	N 4.5		N 9.5	N 11.5	N 2.5		N 9	N 10.5	N 3.5		N 8.5	N 10.5	0	
Apr........	N 2		N 10.5	N 10.5 N2.5	N 3.5		N 10.5	N 11.5	N2 N 3.5		N 10.5	N 10.5	N 2		N 8.5	N 11	N 2		N 7.5	N 10	N 11.5	N 11	N 2	N 2		N 7.5	N 10	N 11	N 2	N 2.5 N4	■	0	
May		N 8.5	N 10	N 10	N 2	N 2		N 8.5			N 2		N 8.5	N 10	N 11.5 N2	N1 N3		N 8.5	N 10	N 11.5	N 11.5	N 3.5		N 9.5	N 10	N 2	N 2		N 8	N 11.5	N 2	0	
June		N 8	N 10	N 11.5	N 1.5		N 10	N 10	N 10	N 11.5	N 1.5		N 1.5		N 2		N 8.5	N 10.5	N 2		N 10	N 11.5	N 2	N 8.5	N8 N 10	N 11.5	N 1.5		N 8	N 10	■	0	
July........	N 10.5	N 11.5	N 2	N 3		N 8.5	N 10.5	N 2																		N 7.5		N 11 N2		N 1.5		0	
Aug........	N 8.5	N 12 N 2.5		N 11	N 4		N 8.5	N 11	N 2.5		N 8.5	N 10	N 4		N 8.5	N 12	N 2	N 8.5	N 11	N 10.5	N 1.5	N 4		N 8.5	N 11	N 1.5		N 10	N 11.5	N 3.5		0	
Sept.......	N 9	N 11.5	N 3.5		N 10	N 1.5		N 10	N 2.5	N 4		N 8.5	N 12	N 3		N 10	N 4		N 8.5 N 11.5	N 1	N 3.5		N 9.5	N 1.5		N 11.5	N 4		N 10.5	N 1.5	■	0	
Oct........		N. 11			N 11.5 N1		N 11.5		N 1.5																							0	

FIG. 13. (*Concluded.*)

Years' Total 0

others are probably the result of the environment, since it is well known that nonproductive periods can be induced by artificial means.

One of the most interesting things in connection with the rhythm of egg production as observed by Pearl ('12) is the existence of hens which never lay an egg, but the record of whose visits to the nests shows a very definite rhythm. A number of such hens have appeared in our flocks. (Nos. 5032 and 246, Fig. 13.) The hour of their visits to the nest exhibits exactly the same sort of rhythm as normal hens. These facts point strongly to the existence of some mechanism other than the formation and deposition of an egg which controls the extrusion of the egg. It is interesting to note that if one of these hens is removed from the nest before she is ready to leave, she returns and persists in doing so until, shall we say, she thinks she has laid her egg. Autopsies of several of these hens show that they fall into two classes; viz., those that are producing yolks or eggs but depositing them in the abdominal cavity, and those in which a tumor of the reproductive system is involved.

Laying hens often visit the nest at the proper day and hour but fail to lay. Such hens (No. 4529, Fig. 13) usually lay the day previous and the day after in regular routine, though at times they may pay two or more such nonproductive visits in succession.

A study of these latter records shows that some hens have indications of a potential capacity greater than the actual capacity revealed in the records. Very many hens pay an occasional visit to the trap nest without laying (note the *n*'s in the various records), while a few pay such visits more or less regularly, at various periods of their lives. The striking feature of these visits is that they are made at the hours one would expect if an egg were actually laid (No. 4529, Fig. 13), though the nature of the stimulus that causes such visits is uncertain.

Broodiness.—Broodiness, from the commercial as well as biological standpoint, is one of the most important of the factors influencing egg production. In general, with the onset of the first broody period, the monthly production falls off 40 per cent. of its former rate. Broodiness, however, as met with in the laying hen, is to some extent an artificial condition. In a free state a hen becomes broody after she has laid a clutch of eggs, incubates them, and rears a brood of chickens. Altogether she is not producing eggs for a period of some ten weeks or more. After this she may again lay a clutch and repeat the process. Egg production under such conditions remains at a relatively low ebb. It is a matter of common knowledge among poultry keepers, however, that by various means the broody hen can be "broken up." That is, she can be induced to discontinue manifestations of broodiness and after a period varying from a few days to several weeks will begin to lay again. As a rule, however, only a few—ten or twelve—eggs are laid before a hen goes broody again. The process may be repeated indefinitely.

There is a considerable variation in the number of times a hen goes broody in a year, the length of the broody periods, the trouble required to break her up and other characteristics of broodiness.

The age at which the first broody period occurs depends in part upon the time a hen begins to lay. In the vast majority of instances egg production precedes broodiness. At least 15 to 20 eggs are laid before a hen becomes broody, though it may be many times that number. *Age incidence* in the first place depends upon the age at which the hen lays her first egg but after that it depends upon other circumstances, which have not been determined. Thus, the age of a bird at her first broody period may vary from eight months up to the end of the second year. Usually, however, the first broody period comes on when the bird is from 11 to 15 months of age. After the first broody period, the periods recur about once a month, if the hen is promptly broken up. There are records in our files of a few Rhode Island Red hens that have not been broody for from one to three laying years.[5]

The number of broody periods per year, then, depends upon the date of the first period and in the second place upon the cessation of production in the fall. Egg production usually, but not always, ceases with a broody period.

A broody period has two phases. First, the period of manifestations of broodiness such as clucking, ruffling of feathers and cessation of production. This period is variable, some hens being easy to "break up" while others are very difficult. Manifestations of broodiness sometimes begin several days before egg production ceases, and may rarely continue without cessation of egg production or without hanging to the nest. I do not recall a case when egg production began before the cessation of the manifestations of broodiness.

The second phase begins with the disappearance of the manifestations of broodiness, and extends up to the time egg laying recommences. Its chief characteristic is nonproductiveness and its length varies considerably.

Broody periods coming during the height of production, March and April, are usually of short duration, but gradually lengthen as the summer advances, until they sometimes last for a month or more. During the winter months, the periods are longer than those occurring during the spring and often lead to the cessation of egg production for several months.

Egg production is affected by broodiness chiefly through the number of broody periods. Hens that go broody many times during the year have a much lower production than others that go broody only two or three times, other things being equal. It is of particular interest to note the abrupt way in which the monthly egg production usually decreases with the onset of broodiness, regardless of the time of the year. Thus, a hen may be laying at a 75 per cent. rate before going broody, but with the appearance of the first broody period production falls off 40 per cent. of its former rate. In general it has been found that for each hen the rate for the broody part of the year is only about 60 per cent. of the rate of the nonbroody part.

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[5] The statements in this section are based on an intensive study of broodiness, the data on which will be published in due course of time.

It is not known whether the intense development of broodiness in the summer months is directly due to the weather conditions as such or whether it is due to some internal cause or is part of the annual cycle. At any rate it is evident that it operates to decrease the egg production very considerably. Further discussion will be postponed until the study of broodiness now in progress is ready for publication.

Types of Winter Records.—The various factors described in the foregoing pages combine in many ways and produce as a result different types of records, several of which may now be discussed in more detail. For the present we may divide the various types of records into high (over 30 eggs), mediocre (under 30 eggs) and zero producers.

High producers (over 30 eggs) may be divided into several subclasses. First, the early maturing, nonbroody high that lays continuously at a high rate and makes a very high record (No. 4846, Fig. 3). Second, the late maturing nonbroody high that lays continuously at a high rate but makes a lower record than the first in direct proportion to the difference in maturity. (See Figs. 3 and 4.) Third, the broody, early maturing high that lays at a high or fairly high rate during the laying periods (not shown). Such a bird's record is cut very materially by the broody periods. Individuals of this type are not very numerous during the winter period. Fourth, there is the high bird that exhibits a pronounced winter cycle or period of good production during the early part of the winter, but which stops after a time and may not lay at all for several weeks. This type is closely related to the bird that lays her eggs in clutches, but because of her early start makes a comparatively high record. Finally there is the type of bird shown by No. 4797, Fig. 11, that matures early, lays steadily and does not go broody but lays at a comparatively slow rate. Such birds may make high records, but they never make the highest ones.

Mediocre producers (under thirty eggs) may result from any one of the various types previously described for high producers through the failure of one or more factors. Thus, delayed maturity will cause a bird to fall below the dividing line at 30 eggs to a degree that will vary inversely with the age at first egg, due allowances being made for the date at which the individual was hatched (Fig. 4). Or a bird may fall below the required number of eggs through a slow rate of production (No. 5080, Fig. 11, or Nos. 224 or 284, Fig. 12). The former type of bird (Fig. 4) would seem to be a late maturing high, since it is clear that its record results directly from the variability in time of first egg. Hence this type of mediocre producer is to be regarded as an artificial class rather than a real class as in the case of the birds typified by No. 5080.

Zero producers, by definition, are birds that do not lay until after March 1, and need no further discussion, except to note that some of them clearly result from the combined effects of date of hatch and age at first egg rather than from an inherent inability to lay during the winter (*i. e.,* from a lack of the winter cycle).

There are, then, numerous types of records resulting from the interaction of the various components described in the earlier part of the paper. Although the records described are winter records, the observations apply equally to annual egg production. High egg production results only from a combination of the right set of factors. If any one of several of these factors fail, egg production is lowered.

(To be concluded.)